Multi-tasking, Memory Failures, and a Perspective on Human Error

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FAA Northwest Region Runway Summit
23-24 July 2008

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Overview

- Most runway incursions are attributed to human error, especially pilot error
- Human factors perspective on why highly skilled experts make errors performing routine tasks
- Runway incursions occur for same underlying reasons as errors made in other phases of flight
- Will focus on one particular type of error as an illustration
  - often contributes to incursions
  - contributed to many other accidents

Two Representative Accidents

LAX, 1991

- Tower cleared commuter to position & hold on 24L
- Delay to cross other aircraft on far end of runway
- Poor visibility: twilight, haze, & glare from lights
- Controller forgot commuter not departed or confused with another commuter
- Cleared B737 to land on 24L
- Both aircraft destroyed; 34 killed

LaGuardia, 1994

- Captain inadvertently forgot to turn on pitot heat
- Pitot probe froze
- Captain rejected takeoff because of anomalous airspeed indications
- Aircraft ran off end of runway, destroying aircraft; 30 minor injuries

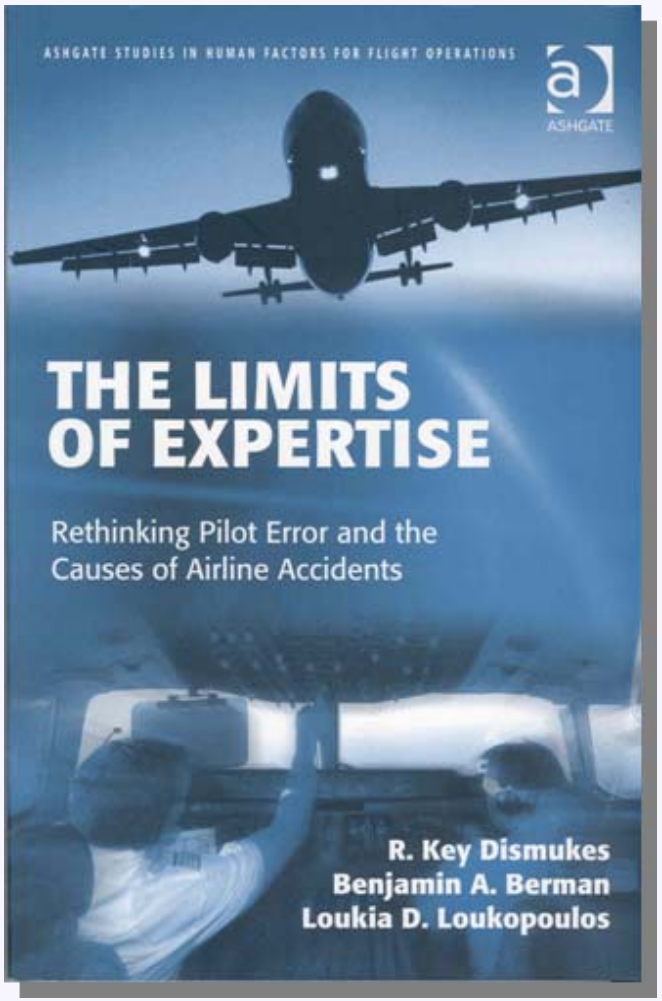
Why?

Why would highly experienced controllers and pilots forget to perform routine tasks?

- Carelessness?
- Lack of skill or proficiency?
- Overwhelmed by workload?
- More subtle issues?

A NASA Study: The Limits of Expertise

Key Dismukes, Ben Berman, and Loukia Loukopoulos



- Re-examined all major U.S. airline accidents 1991-2000 attributed to crew error
- Why might any crew in position of accident crew, and knowing only what accident crew knew, be vulnerable to same errors?
- Traced interaction of task demands, equipment features, events, and organizational factors with human cognitive processes

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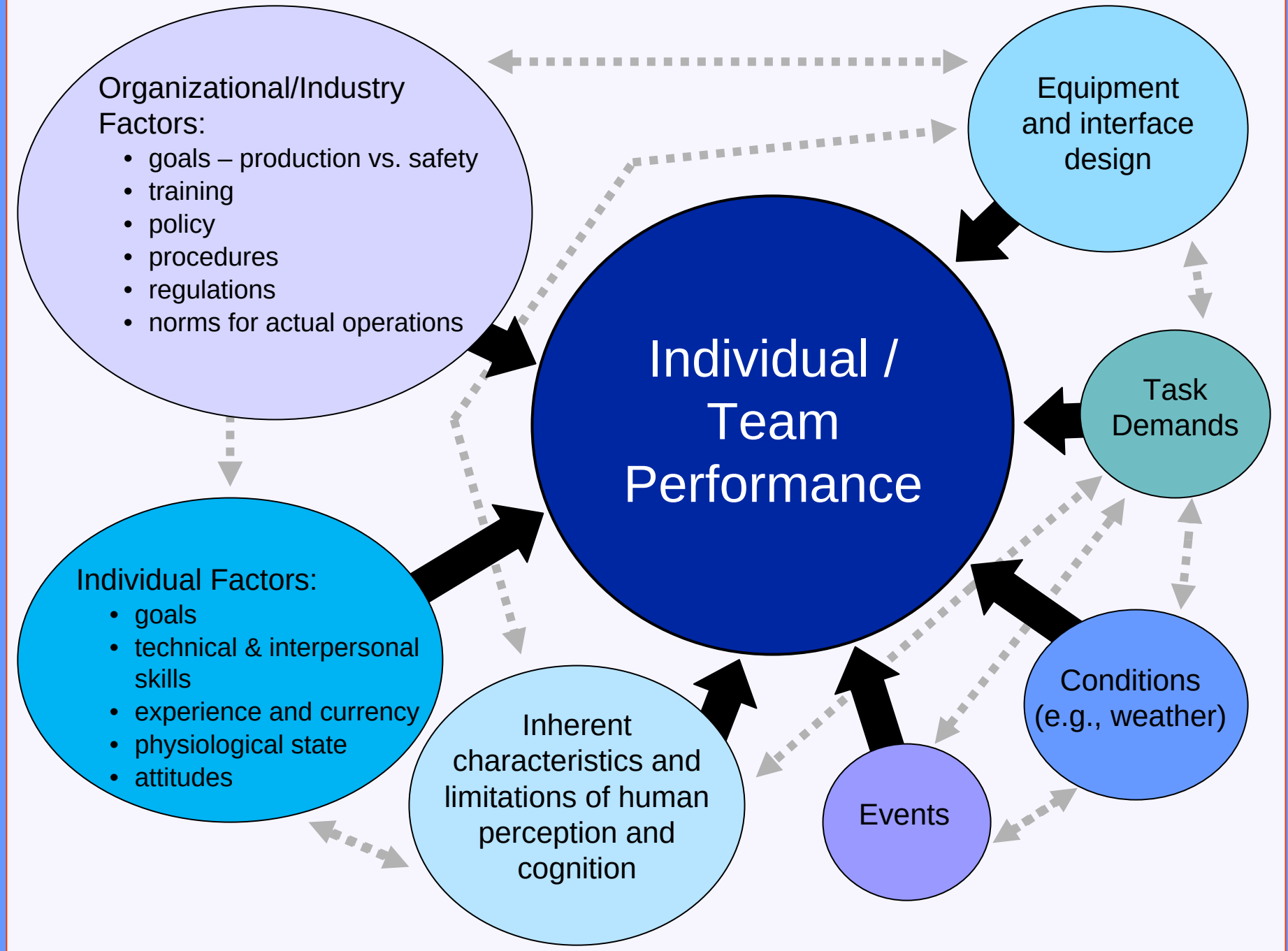
Understanding Accidents

- Highly diverse: each accident is unique in terms of surface features
- Countermeasures developed after accident prevent recurrence
  - But would that accident happen again anyway?
- Single-point failures rarely cause accidents in airline operations
  - Multiple happenstance factors combine to defeat defenses
- To maintain/improve safety must look beyond surface features
  - What underlying features cut across accidents?


Organizational/Industry Factors:
• goals – production vs. safety
• training
• policy
• procedures
• regulations
• norms for actual operations
Equipment and interface design
Individual / Team Performance
Task Demands
Individual Factors:
• goals
• technical & interpersonal skills
• experience and currency
• physiological state
• attitudes
Inherent characteristics and limitations of human perception and cognition
Events
Conditions (e.g., weather)

Two Fallacies About Human Error

- **MYTH:** Experts who make errors performing a familiar task reveal lack of skill, vigilance, or conscientiousness

- **FACT:** Skill, vigilance, and conscientiousness are essential but not sufficient to prevent error

- **MYTH:** If experts can normally perform a task without difficulty, they should always be able to perform that task correctly

- **FACT:** Exerts periodically make errors as consequence of subtle variations in task demands, information available, and cognitive processing

Some Argue Solution to Human Error is Automation

- This perspective ignores the nature of work of pilots and controllers

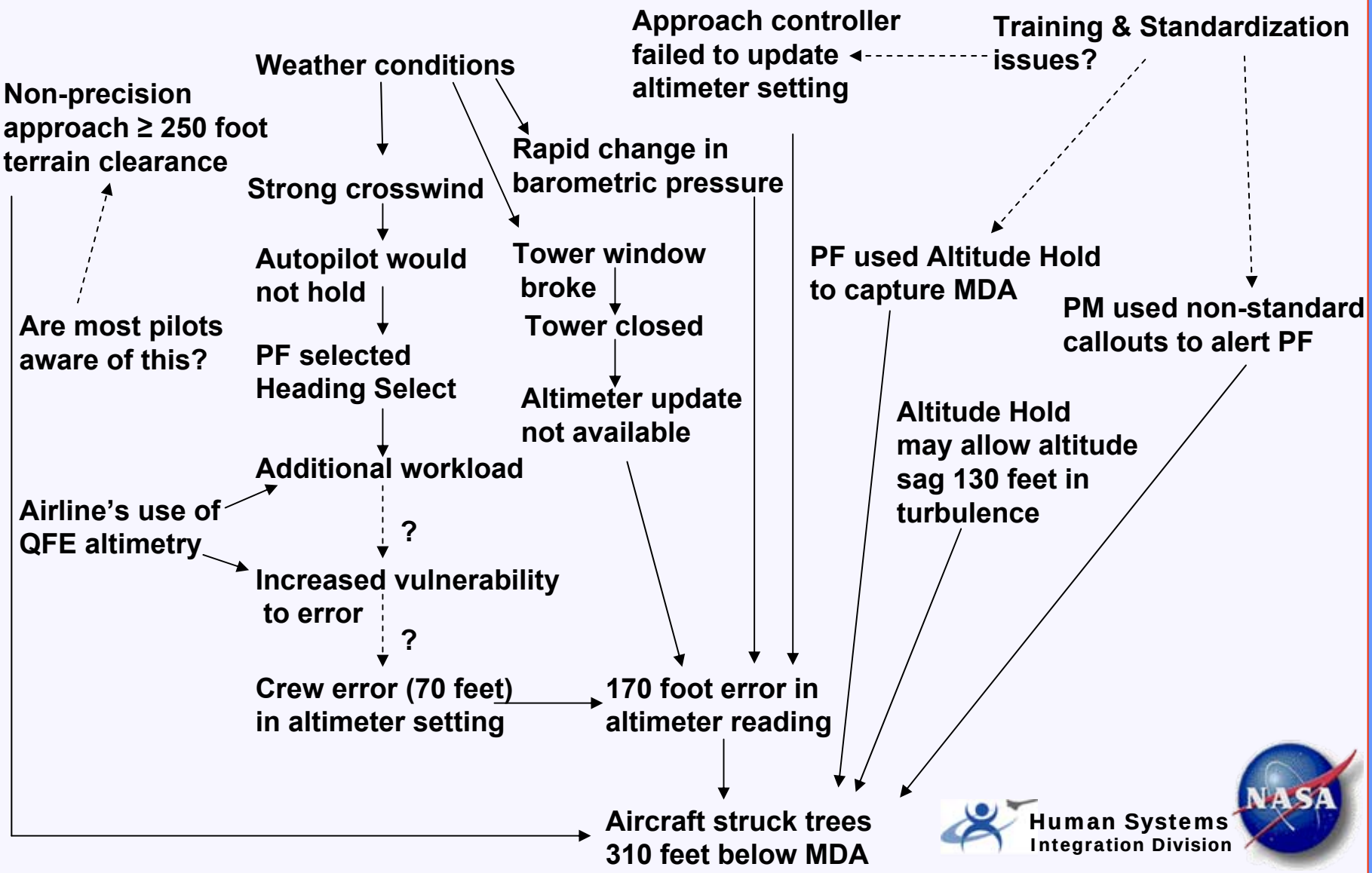
- Humans do what computers cannot:
  - Interpret incomplete or ambiguous information
  - Consider implications
  - Make appropriate value judgments and decisions

A Modern System Safety Perspective

- Experts make errors for three kinds of reasons:
  - Lack of information to be certain of outcome of competing choices
  - Task demands and equipment not well matched to human information processing characteristics
  - Competing organizational goals must be balanced (e.g., production vs. safety)
- Mathematically impossible to simultaneously maximize two or more variables
- Accidents result from interactions among components of complex systems that are not anticipated and controlled

Confluence of Factors in a CFIT Accident

(Bradley, 1995)



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To Prevent Runway Incursions…

- Start with thorough analysis of large volume of incidents from operational and human factors perspective
- See work by Kim Cardosi and colleagues at Volpe Transportation Center
- My research examines two issues identified by Cardosi, et al.:

• Multi-tasking

• Prospective memory failures

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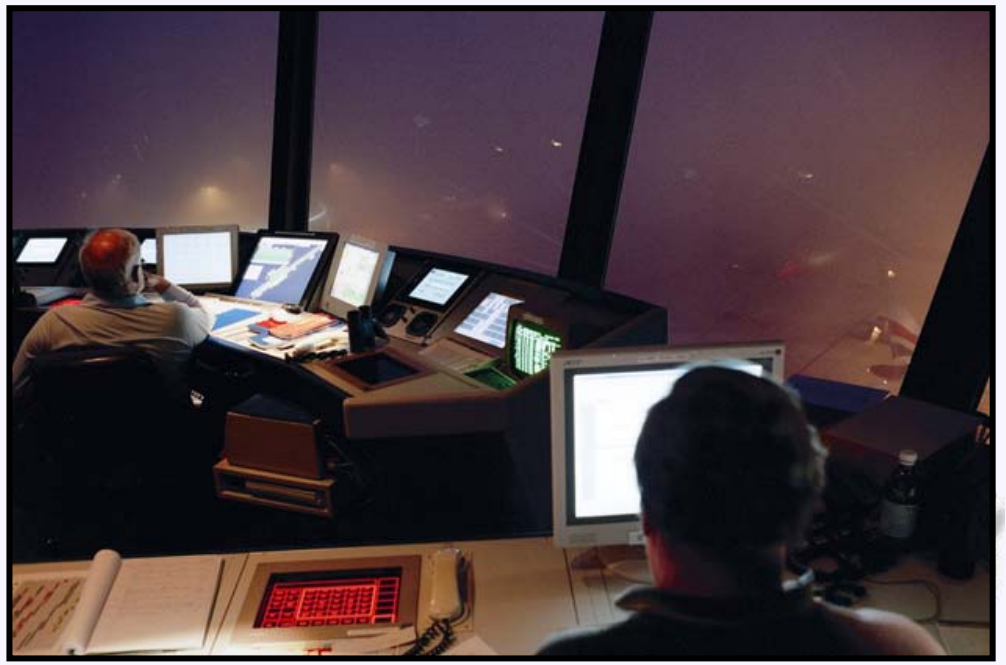
Multi-tasking and Prospective Memory

- Multi-tasking demands are heavy in work of controllers and pilots

- Prospective memory: Individual must remember to perform a task that cannot be performed when the intention to act is formed
  - Cardosi: forgetting was most common form of controller error
  - Did not forget content (e.g., call sign)
  - Forgot to act or forgot implications of current situation for what they should or should not do later

- Examples: LAX, 1991; LaGuardia, 1994



WHY???

How could experienced operators forget to perform simple tasks with monumental consequences?

- Importance of task does not protect against forgetting at crucial moments
  - Surgical teams forget to remove instruments
  - Parents forget infants sleeping in the back seat of the car
- Workload? Sometimes high but, more often than not, normal
  - LAX and LaGuardia accidents were within typical workload range

Our Research: Forget to Act in Six Prototypical Situations

- Interruptions
  - e.g., Controller interrupted before turning aircraft onto final
- Non-habitual tasks that must be deferred
  - e.g., “Report passing through 10,000 feet”
- Attention switching among multiple concurrent tasks
  - e.g., First officer re-programming the FMC during taxi
- Habitual tasks with normal trigger cues removed
  - e.g., “Go to tower at final approach fix”
- Habitual tasks performed out of the normal sequence
  - e.g., Setting flaps delayed because of slush on taxiway
- Habit capture (atypical action must be substituted for habitual action)
  - e.g., Modified standard instrument departure

A Quick Sketch of the Science

- Six prototypical situations appear diverse but share underlying features:
  - Pilots or controllers were juggling multiple tasks concurrently
  - Had to remember to perform deferred task or perform task out of normal sequence
- Individuals forget to act because characteristics of these situations interact with the way the human brain processes information

Human Brain: Two Ways to Process Information

- "Controlled" processing (fully attentive):
  - Required when learning new tasks, performing tasks with novel aspects and tasks that are unusually dangerous or difficult, and when solving problems
  - Corresponds roughly to conscious awareness
  - Slow, serial, effortful (narrow-bandwidth, low capacity)
- Automatic processing:
  - Takes over as we master specific task
  - Fast, high-capacity, requires minimal conscious supervision
  - Essential for much of experts' work
  - Drawback: powerful but dumb; unreliable in certain situations

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Non-Habitual Situations: An Everyday Example

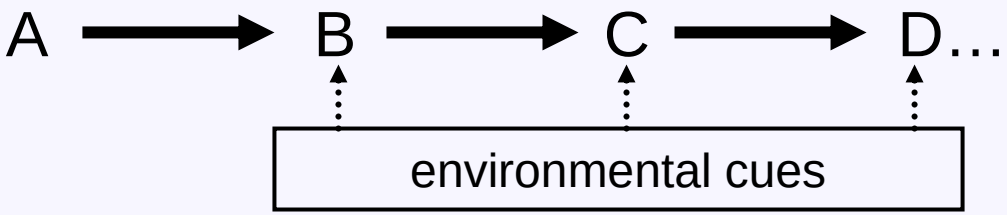
- Deferred intention: Pick up milk on way home from work
- Intention cannot be held in conscious awareness throughout the day – moves to memory
- How is intention retrieved from memory back into awareness?
  - Requires noticing salient cue to remind of intention (get milk)
  - Cue must occur at time action required (driving home)
- What makes a good reminder cue?
  - Placed where it will be noted when needed (e.g., on car dashboard)
  - Clearly related to deferred intention (e.g., empty milk carton = get milk)

Non-habitual Situations: A Cockpit Example

- "Report passing through 10,000 feet"
- Crew must attend to other tasks for several minutes before reaching 10,000 feet
  - Intention to report moves from conscious awareness to memory
  - Cannot monitor altimeter continuously
- Crew may notice altimeter during scan, but it is a mediocre cue
  - Altimeter associated with many items in memory, not just reporting 10,000 feet

Non-habitual Tasks

- With extensive repetition, no longer have to think what to do next – automatic
  - e.g., complete After Start checklist → call for flaps
- Most tasks consist of a series of subtasks



- Normally highly reliable but vulnerable if cueing is disrupted
  - Subtasks performed out of sequence (e.g., deferred subtask)
  - Interruptions (e.g., controller distracted by emergency)

Other Factors Affecting Vulnerability to Forgetting to Act

- Organizational / industry factors
  - e.g., rushing to make slot time; trying to beat T-storms to airport
- Design of procedures
  - e.g., running checklists when both pilots should be heads-up
- Recent study: The Myth of Multi-tasking: Managing Complexity in Real-World Operations (Loukopoulos, Dismukes, & Barshi)
  - Flight operations manuals present idealized picture: tasks are linear, predictable, and under moment-to-moment control of the crew
  - Reality: execution of procedures is frequently perturbed by interruptions, situations change dynamically, and tasks must be performed concurrently

Practical Countermeasures to Reduce Error Vulnerability

1) Discard “blame and punish” mentality when experts make mistakes

2) Periodically analyze SOPs to indentify aspects that contribute to vulnerability

3) Use training to explain why expert pilots and controllers are vulnerable to error
   - Evaluate and share personal techniques to reduce vulnerability to error

4) Treat monitoring as essential rather than secondary task

5) Don’t underestimate subtle effects of fatigue on cognitive performance

6) Do the research!
   - Procedures, training, and equipment design must be based on science

Additional Information

- Can download papers from:
  http://human-factors.arc.nasa.gov/ihs/flightcognition/

- Dismukes, Berman, & Loukopoulos (2007). The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents (Ashgate Publishing)

- Loukopoulos, Dismukes, & Barshi (in press). The Myth of Multitasking: Managing Complexity in Real-World Operations (Ashgate Publishing)

- Cardosi (2001). Runway Safety: It's Everybody's Business. DOT/FAA/AR-01/66

- Cardosi & Yost (2001). Controller and Pilot Error in Airport Operations. DOT/FAA/AR-00/51

- DiFiore & Cardosi (2006). Human Factors in Airport Surface Incidents. DOT/FAA/AR-06/5

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